WARD'S™

Effect of pH on Hydroponically Grown Plants

Student Study Guide

36 W 6090

Introduction

Pollutants that are put directly into the air by human activity are referred to as primary pollutants. Most of these pollutants result from the burning of fossil fuels, especially coal, oil, and gas. When a primary pollutant comes into contact with another substance in the atmosphere, a chemical reaction sometimes takes place and a secondary pollutant is formed. Some examples of secondary pollutants are sulfur dioxide (SO_2) and nitrogen dioxide (NO_2). The following formulas summarize these chemical reactions:

$$S + O_2 \rightarrow SO_2$$

$$2\ SO_2 + O_2 \rightarrow 2\ SO_3$$

$$SO_3 + H_2O \rightarrow H_2SO_4$$

When these emissions are released into the atmosphere, they become oxidized and form ions (molecules which have gained or lost electons). These ions may combine with hydrogen atoms and other components such as ammonia, ozone, water vapor, and nitric acid. These new compounds then travel in clouds to other regions and eventually fall to earth as acid precipitation thereby polluting an area far from where they were originally produced.

Acid precipitation is almost always detrimental to the environment, because it pollutes fresh water and damages plants, animals, and man-made structures. However, it is usually the plants that are the first to indicate the problem of air pollution by showing signs of damage. This sensitivity is due to the fact that plants lack a protective mucous membrane around their cells, which is normally found in animals. This protective membrane acts as a barrier to the pollution. Because plants lack this membrane, the acid rain weakens them, thus increasing their overall susceptibility to insects, diseases, and other pathogens.

When growing plants without soil, or hydroponically, the pH of the nutrient solution is critical for their proper development. If the pH of the nutrient solution is within the appropriate range for a particular plant, that plant will be able to utilize all the proper nutrients and thrive. If the pH of the nutrient solution is not within the appropriate range for a particular plant, then the plant will not be able to utilize an adequate amount of nutrients and will begin to show signs of poor health such as fragile stems, yellowish leaves, and slow or stunted growth.

Generally, the visual effects of acid precipitation on plants can be described as being acute, chronic, or suppressive. Acute damage is indicated by markings on the leaves that cause death to cells or whole tissues. This damage can be seen when a plant is suddenly exposed to a highly acidic environment. Chronic damage can be observed as a gradual yellowing of leaf tissue over a period of time. This occurs when acid rain leeches minerals from the soil, depriving plants of essential nutrients. Suppressive effects are indicated by a reduction in growth due to reduced photosynthesis.

Hydroponics

Hydroponics is the growing of plants without soil. Instead, plant roots are supplied with a solution that contains all essential nutrients necessary for plant growth and development. Because these plants spend less energy seeking out nutrients, they grow and develop much more rapidly than plants grown in soil.

Contrary to popular belief, hydroponics is not a new technology. It is believed that the hanging gardens of Babylon may have been the first hydroponic gardens used for food production and that the Aztecs grew crops on floating reed rafts in shallow lakes. Today, in Mexico City, rafts float in park lakes bearing beautiful flowers.

In the late 17th century, John Woodward, an English physician, discovered that plants grown in water did not grow as well as plants grown in a solution containing essential plant nutrients. In 1860, the German researchers Sachs and Knop developed nutrient solution formulas and solution cultures for research on essential plant requirements. In 1929, a plant physiologist by the name of William Gericke used these nutrient solution formulas to grow crops and called the process "aquaculture". However, that term was being used for another process, so Gericke instead coined the word "hydroponics".

During World War II, hydroponics was used to supply U.S. troops with fresh food. Vegetables were grown hydroponically on rock islands in the Pacific, as well as on submarines. With the invention of plastic during the 1950s, hydroponics started to become more mainstream and was no longer limited to just the military or the lab.

Recent widespread destruction of the environment in many areas has resulted in the use of hydroponics as an alternative means of growing food in places where it would be difficult to grow healthy crops. Hydroponic greenhouses have been built throughout the world and currently supply fresh produce to local markets year round. Some areas that use hydroponics extensively include South Africa, the Middle East, Israel, and the Netherlands, to name a few. Hydroponics is also used to grow crops in all fifty U.S. states, thus providing food to a rapidly growing population.

In addition, hydroponics is playing an important role in the exploration of Earth and space. The scientists at the Antarctica Research Station utilize hydroponics to grow fresh food during the dark, gloomy Antarctic winters, while NASA scientists have been experimenting with the practicality of hydroponics in space, not only as a means of providing fresh food for space travelers, but as a means of recycling water in space ships and space stations. Perhaps in the future, hydroponics will be used to provide fresh foods on intergalactic journeys.

A simple hydroponic system is comprised of a planting container, planting medium, a reservoir, a wick, air space, and a light source. The planting container holds the planting media where the plant or seed is grown. The planting medium is an inert material such as perlite, vermiculite, rock wool, clay pellets, or other commercially available substances. It may also be a mixture of media. The wick is usually a narrow strip of felt used to transport and disperse the nutrient solution from the reservoir to the roots of the plant. The air space is located between the top of the nutrient solution in the lower container and the bottom of the planting container. This space allows the plant's roots to receive needed oxygen for healthy growth. The light source can be natural or artificially provided. It supplies the plant with the necessary energy to carry out photosynthesis.

All plants manufacture their own food through a process called photosynthesis. Certain elements are needed by plants in order to carry out this amazing process. Carbon, hydrogen, and oxygen are obtained from air and water, but all other elements must be provided. With hydroponics, the nutrient solution provides elements usually supplied as salts by the soil. Although certain plants have different nutrient requirements, all plants require macro- and micronutrients. Macronutrients include nitrogen, phosphorous, potassium, magnesium, sulfur, and calcium. Micronutrients include iron, manganese, boron, zinc, copper, and molybdenum.

Objective

You will simulate exposure to acid rain and other pollutants by substituting normal nutrient solution with a nutrient solution adjusted to a pH of between 3.0 and 8.0. During this time, you will determine the effects of pH by observing the solution pH, growth rate, leaf and stem color, general appearance and mortality rate.

Materials Needed Per Group

4 Small containers (24 oz.)

4 Large containers (32 oz.)

1 Plant Tray

8 Bush bean seeds

Nutrient solution

pH Up

pH Down

pH test strips

1 Metric ruler

4 Felt strips

Perlite

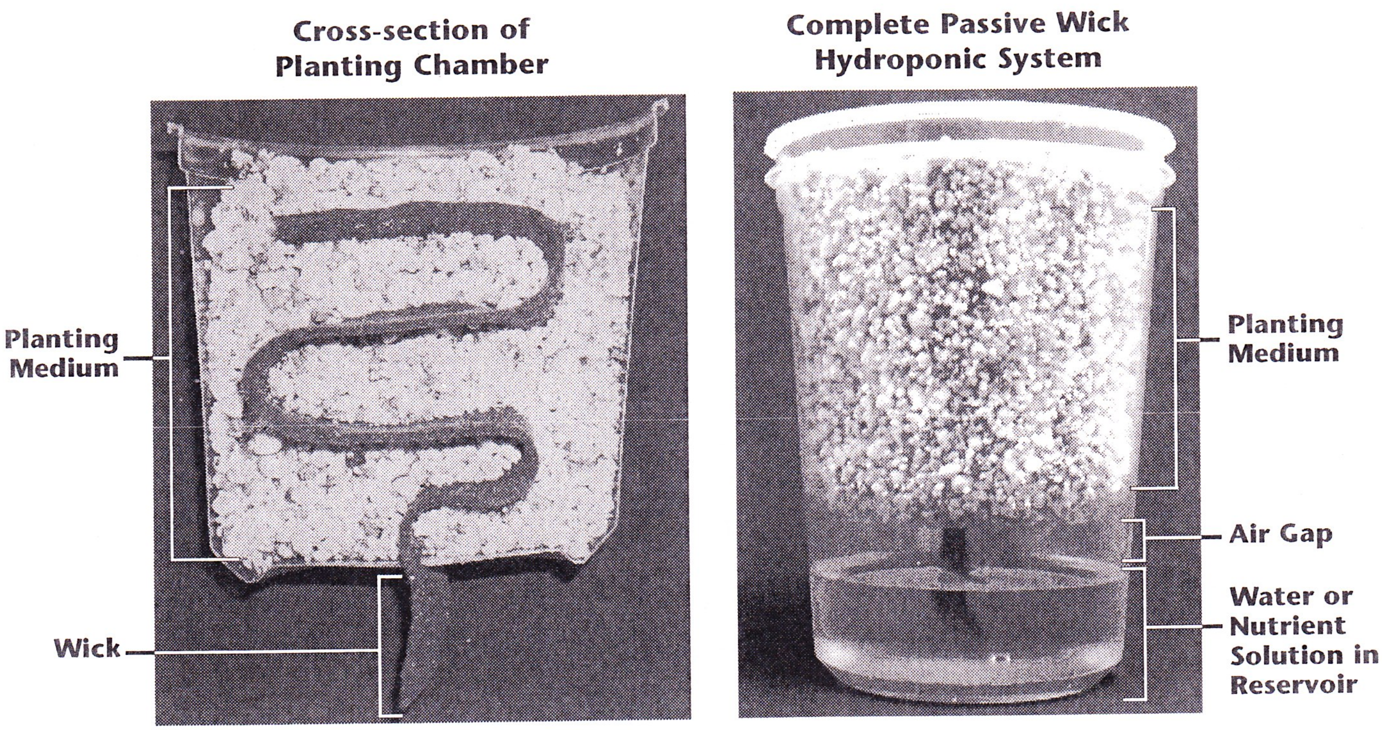
Vermiculite

Procedure

Part A: Setting-up the Hydroponic Passive Wick Systems & Planting Seeds

1. State your hypothesis about the effects of nutrient solution pH on hydroponic plant growth and record it in the space provided in the Group Data Observation Worksheet.
2. Moisten the planting media to reduce dust and particulate matter. Mix the moistened perlite and vermiculite in the ratio of 7:3; seven units of perlite to three units of vermiculite (approximately 19 oz. of perlite to 8 oz. of vermiculite).
3. Thread the wick through the slit in the bottom of the smaller container. Leave about 1″ of the wick extending from the bottom of the container.
4. While placing the planting medium in the smaller container, simultaneously weave the wick in an "s" shape throughout the container (figure 2). This will allow the nutrient solution to be diffused throughout the planting medium.

Figure 2



5. Place approximately 200 ml of water in the larger container (reservoir) and place the smaller container, holding the planting medium, into the larger container.
6. Allow the system to sit for two days. Check to make sure the wick is transporting the water upward. The planting medium and the entire wick should remain moist at all times.
7. Plant two bush bean seeds per system, spaced about 1″ apart, at a depth of approximately $^1/_2$″. Cover with medium (70% perlite/30% vermiculite mix). When the seedlings emerge, thin to one plant per system. Keep the healthiest, strongest plant.
8. When the seeds have germinated and the seed leaves appear, replace the water with approximately 200 ml of nutrient solution mixed according to the instructions on the label.

   Note: *Use nutrient solution that has not been adjusted for pH. Test the nutrient solution to determine its unaltered pH. Normally, the unaltered pH will be between 6.5 and 7.0. Be sure to record this value on the Group Data Observation Sheet along with the planting date. This solution will be used as the control solution once the experiment begins.*
9. Allow the seedlings to grow and stabilize for approximately one week following germination.

Part B: Running the Experiment

1. Using a pH test strip and the pH Up and pH Down solutions, adjust the unaltered nutrient solution to achieve six stock nutrient solutions with pH values of approximately 3.0, 4.0, 5.0, 6.0, 7.0, and 8.0. Place each solution in a separate, labeled container and refill each container with newly-mixed solution as necessary.

   Caution: *Strong acid and alkaline solutions can burn skin. If acids or alkalines get on skin, immediately wash the affected area with water.*

2. Discard the nutrient solution from the initial germination period and replace it with approximately 200 ml of the assigned pH solution.

   Note: *Each student group will test four plants. One plant will be utilized for each listed pH value in each student group. The plant containing 7.0 pH nutrient solution will serve as the control plant. Each experimental plant will be assigned a nutrient solution with a different pH value. Each student group's set of four plants contains one control plant and three experimental plants. Group pH assignments are as follows:*

   Group #1 – pH 3.0, 4.0, 6.0, 7.0
   Group #2 – pH 3.0, 4.0, 7.0, 8.0
   Group #3 – pH 3.0, 5.0, 6.0, 7.0
   Group #4 – pH 3.0, 5.0, 7.0, 8.0
   Group #5 – pH 4.0, 5.0, 6.0, 7.0
   Group #6 – pH 4.0, 5.0, 7.0, 8.0
   Group #7 – pH 4.0, 6.0, 7.0, 8.0
   Group #8 – pH 5.0, 6.0, 7.0, 8.0

3. Using a waterproof marker, indicate the group number and pH value on each reservoir.
4. Place each group's plants in a plant tray and identify the tray with the appropriate group number.
5. Place all plant trays under the light source.
6. Measure the height (cm) and count and record the number of leaves of each plant. Record all observations in table 1 on the Group Data Observation Worksheet. Also, observe and record leaf and stem color, stem thickness, discolorations (spots, scarring, etc.), abnormal leaf shape, and other general observations in table 1. Repeat this step at least two times per week with a new Group Data Observation Worksheet.
7. Check the nutrient solution level at least twice per week as well. Add the appropriate nutrient solution as needed and discard and replace nutrient solution every two weeks.

   Note: *Do NOT use pH-adjusted nutrient solution to water other plants. Simply pour the nutrient solution into a marked container, adjust the pH to approximately 7.0, and discard.*

8. At the conclusion of the experiment, after four to five weeks, compile the class results by completing table 2 on the Class Final Analysis Worksheet.
9. Using the information obtained from table 2, generate a bar graph on the graph paper provided. Put the pH (independent variable) on the horizontal axis and the average height in centimeters (dependent variable) on the vertical axis. Be sure to label each axis and include a key and a title for your graph (figure 3).

Observations

Group Data Observation Worksheet

Name: ______________________________ Group Number: __________ Date: __________

Group Members ______________________________

____

____

____

pH Values Tested:

________ ________ ________ ________

Initial Unaltered pH Value: ________

Hypothesis: ____

____

____

____

____

Table 1

System Number	pH	Height (cm)	Leaf Color	Stem Color	Other Observations: General Appearance, Mortality
1					
2					
3					
4					

Analysis

Class Final Analysis Worksheet

Name: ______________________ Group Number: __________ Date: __________

Group Members ______________________ ______________________

______________________ ______________________

* To find the averages for each chart, add the individual group values for each pH and divide by the number of groups for that pH.

Table 2
Average Height (cm) for Each pH

Ph	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	Total of Heights	Average Total Height*
3.0										
4.0										
5.0										
6.0										
7.0										
8.0										

Questions

1. What pH value produced the greatest plant growth? Does this growth accurately reflect the health of these plants?

2. What pH values produced the poorest growth? Describe how you arrived at this conclusion.

3. Refer back to your original hypothesis. Was your hypothesis supported ?

4. If not, explain how it was different.

5. Based on the results of the experiment, if you were to repeat it, what would be your revised hypothesis? Be sure to use an "if...then..." statement.

6. If you were to do this experiment over, how could you improve it?

7. Discuss what you learned from this experiment about the effect of pH on all physical properties of the plants and the rate at which these took place?